AD-A062 446 COLD REGIONS RESEARCH AND ENGINEERING LAB HANOVER N H F/G 13/6
EFFECTS OF LOW GROUND PRESSURE VEHICLE TRAFFIC ON TUNDRA AT LON--ETC(U)
SEP 77 G ABELE, J BROWN, M C BREWER

UNCLASSIFIED CRREL-SR-77-31 NL

| OF |

AD
A062446

END
DATE
FILMED
3-79
DDC

SR 77-31

CRREL

(1)

Special Report 77-31

LEVEL II

EFFECTS OF LOW GROUND PRESSURE VEHICLE TRAFFIC ON TUNDRA AT LONELY, ALASKA

G. Abele, J. Brown, M.C. Brewer and D.M. Atwood

September 1977

Prepared for
DIRECTORATE OF FACILITIES ENGINEERING
OFFICE, CHIEF OF ENGINEERS
By
CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: 1 Special Report 77-31 — 2. GOVT ACCESSION NO. 14 CRREL-SR-77-31	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): 6 EFFECTS OF LOW GROUND PRESSURE VEHICLE TRAFFIC ON TUNDRA AT LONELY, ALASKA	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 G. Abele, J. Brown, M.C. Brewer ~~and~~ D.M. Atwood	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 16 DA Project 4A161102AT24, Task A2, Work Unit 002
11. CONTROLLING OFFICE NAME AND ADDRESS: Directorate of Facilities Engineering, Office, Chief of Engineers, Washington, DC 02314	12. REPORT DATE: 11 Sep[redacted]1977
	13. NUMBER OF PAGES: 38
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 39p.	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: 17 A2

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Low-pressure vehicles
Traffic
Tundra

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Traffic tests were conducted with two low pressure tire Rolligon-type vehicles and a small, tracked Nodwell with minimal load for 1, 5, and 10 vehicle passes on relatively dry tundra near Lonely, Alaska. The traffic impact was limited to compression of the vegetation and the organic mat and a maximum terrain surface depression of several cm, with no shearing or disaggregation of the mat.

78 12 18 085

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

037 100

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This study was conducted and this report was prepared by Gunars Abele, Research Civil Engineer, Applied Research Branch, Experimental Engineering Division; Dr. Jerry Brown, Soil Scientist, Earth Sciences Branch, Research Division; David M. Atwood, Photographer, Engineering Services Branch, Technical Services Division - U.S. Army Cold Regions Research and Engineering Laboratory; and Dr. Max C. Brewer, Environmentalist, Naval Petroleum Reserve No. 4. Phil Jeans, Camp Manager, Husky Oil, assisted in the field work.

This work was performed under DA Project 4A161102AT24, Research in Snow, Ice, and Frozen Ground; Task A2, Cold Regions Environmental Interactions; Work Unit 002, Cold Regions Environmental Factors.

The Naval Arctic Research Laboratory, Barrow, and the NPR-4 Base Camp at Lonely, operated by Husky Oil, provided logistics support, including facilities, equipment and aircraft. The assistance and approval of Lieutenant Commander A.E. Corcoran, Officer in Charge, NPR-4, are greatly appreciated.

CONTENTS

ILLUSTRATIONS

TABLES

NOMENCLATURE

C = CATCO (8-wheel vehicle)

H = Houston (6-wheel vehicle)

N = Nodwell (tracked vehicle)

n = Number of vehicle traffic passes

y_c = Depression of terrain surface under the center of tire (cm)

y_e = Depression of terrain surface under the edge of tire (cm)

h_C = Thaw depth, control area (cm)

h_T = Thaw depth, below track (cm)

$w_{p(C)}$ = Moisture content of peat, control area (%)

$w_{p(T)}$ = Moisture content of peat, below track (%)

$w_{m(C)}$ = Moisture content of mineral soil, control area (%)

$w_{m(T)}$ = Moisture content of mineral soil, below track (%)

$\rho_{p(C)}$ = Dry density of peat, control area (g/cm^3)

$\rho_{p(T)}$ = Dry density of peat, below track (g/cm^3)

$\rho_{m(C)}$ = Dry density of mineral soil, control area (g/cm^3)

$\rho_{m(T)}$ = Dry density of mineral soil, below track (g/cm^3)

INTRODUCTION

The recent increase in the oil exploration activities on the Arctic Coastal Plain of Alaska has resulted in a corresponding increase in surface transportation requirements. Not all traffic can be confined to the winter months when the ecological impact of vehicle operations is less severe. Traffic across tundra during summer can result in effects that vary significantly in the degree of severity depending on the vehicle, traffic and terrain characteristics.

A number of studies have been conducted on the effects of off-road vehicular traffic on tundra, including wheeled, tracked, and air cushion vehicles (Abele, 1976; Abele and Brown, 1977; Burt, 1970a, 1970b; Kevan, 1971; Miller, et. al., 1977; Radforth, 1970, 1972, 1973a, 1973b; Rickard and Brown, 1974; Sterrett, 1976; Walker, et al. in press). As a follow-up to these studies, a series of traffic tests with three different vehicles was performed on tundra near Lonely, Alaska, on 3 August 1976 to obtain additional environmental information which will provide added insight for decisions on operations of Naval Petroleum Reserve No. 4.*

---

* Recently renamed "National Petroleum Reserve - Alaska."

DESCRIPTION OF STUDY

Test Site

Location of the test area, approximately 2 miles south of Lonely, is identified in Figure 1. The immediate test site can be characterized as poorly drained with very weakly developed polygonal ground patterns, virtually no surface relief, and having a relatively uniform vegetation distribution (predominantly Dupontia, Carex, Eriophorum), the organic layer approximately 12 cm thick with a mean water content of approximately 400%, and thaw depth generally in the 20 to 30 cm range.

Test Vehicles

Three vehicles were used for the traffic tests:

1. CATCO Rolligon (11,700 kg or 26,000 lb, empty), an 8-wheel, low pressure, smooth, wide tire vehicle, inflation pressure 0.35 kg/cm^2 (5 psi), minimal load (Fig. 2)

2. Houston Rolligon (6,800 kg or 15,000 lb, empty), a 6-wheel, low pressure, ribbed, wide tire vehicle, inflation pressure 0.2 to 0.3 kg/cm^2 (3 to 4 psi), no load (Fig. 3)

3. Nodwell, FN-10 (2,250 kg or 5000 lb empty), low pressure (0.1 kg/cm^2 or 1.4 psi), tracked vehicle, no load (Fig. 4)

Traffic Test Layout

Aerial views of the traffic test area are shown in Figures 5 and 6. The test lane layout is shown in Figure 7.

The test area consists of three traffic loops, one for each of the three traffic conditions: 1, 5, and 10 passes. Each loop consists of 6 parallel lanes, 2 for each test vehicle, for a total of 18 parallel tests lanes, each approximately 100 meters long. The direction of traffic on each lane is indicated in Figure 7.

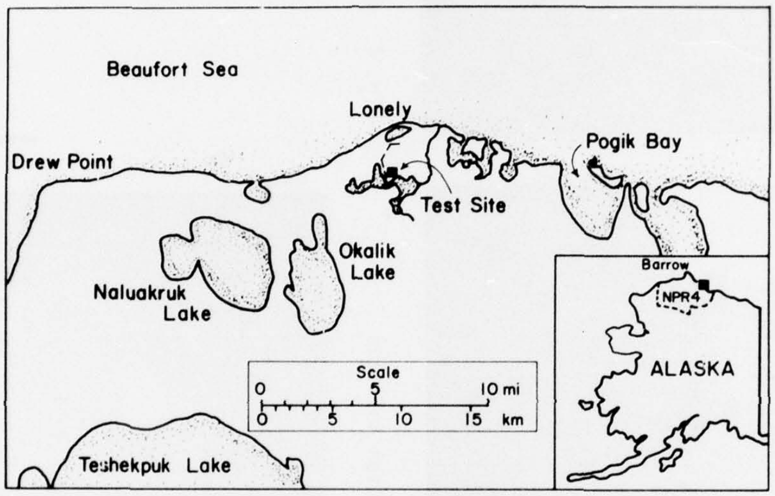


FIGURE 1. Location map

Fig. 2. CATCO Rolligon

Fig. 3. Houston Rolligon

Fig. 4. Nodwell

Fig. 5. Aerial view of test area

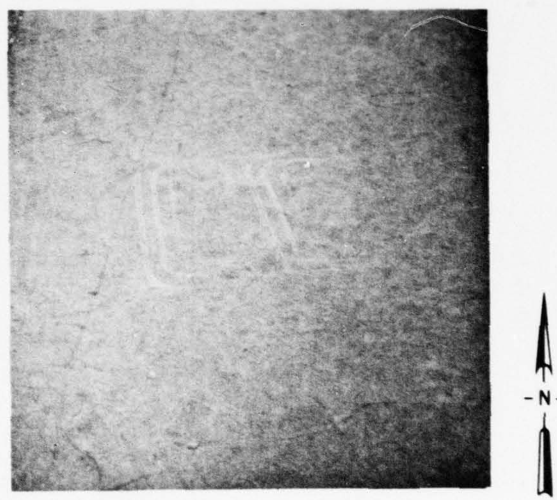


Fig. 6. Aerial view of test area

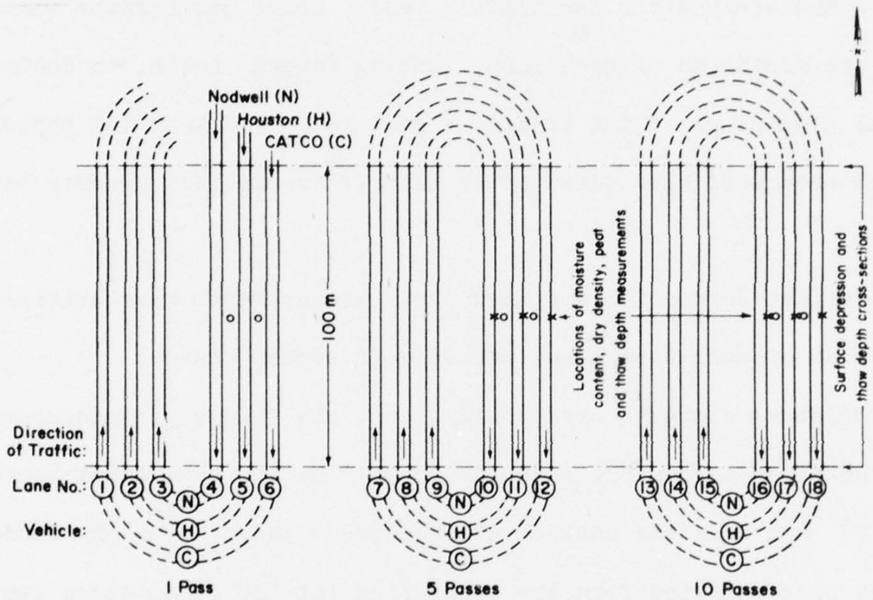


FIGURE 7. Traffic test lane layout

The vehicle speed during the tests was approximately 5 mph (8 km/hr). The traffic tests were completed within a period of a few hours.

Data Obtained

Immediately after the traffic tests, color photographs were taken from the south end of each lane, looking toward north, to document the visual appearance of the traffic signatures. A few aerial photographs of the area were also taken after takeoff from Lonely enroute back to Barrow.

Surface depression and thaw depth measurements were obtained across both ends of each test lane, marked with wooden stakes.

Moisture content, dry density, peat and thaw depth measurements were obtained across the midpoint of some of the test lanes (refer to Fig. 7) and from the control areas between lanes. The dry density values were computed from the oven-dried (at 110°C) moisture samples, obtained in open-end cans and returned to the soils lab in Hanover, N.H. in sealed plastic bags.

All field data and samples were obtained within two hours after the traffic tests.

DISCUSSION OF RESULTS

Photographic Record

Figures 8 through 25 are color photographs of the 18 test lanes, viewed toward north. (The arrow in the caption denotes direction of traffic.)

The traffic signatures, when viewed against the direction of travel, appear darker than the surrounding terrain (Figures 11-13, 17-19, 23-25) and are more visible than when the traffic signatures are viewed in the direction of travel, in which case they appear slightly lighter than the adjacent terrain surface (Figures 8-10, 14-16, 20-22). It is, therefore, usually quite easy to determine the direction in which a vehicle has traveled by merely a quick glance, without close inspection of the vegetation (direction of bending).

The direction of travel of a vehicle is usually even more evident from the air; however, the relative visibility of a traffic signature is influenced by the direction and angle of sunlight relative to the position of the viewer. In this case (Figures 4 and 5), the traffic signatures which were more prominent when viewed from the ground (traffic direction towards the viewer) are barely perceptible when viewed in the same direction from the air a couple of hours later in comparable overcast conditions. Yet the lighter color signatures (traffic direction away from the viewer), which were less obvious from the ground, are quite prominent from the air.

It is, therefore, important to recognize that visual appearance alone of a traffic signature is not necessarily a reliable indicator of the effects of traffic on organic terrains. A cursory visual inspection or photographs, especially aerial, from one particular position are not dependable means for estimating the relative ecological impact of vehicular traffic on tundra.

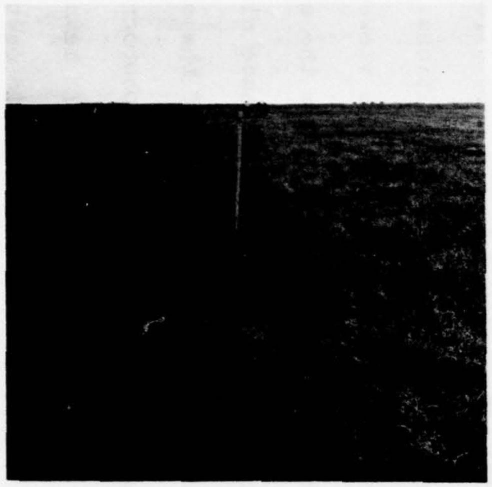


Fig. 8. 1 pass, CATCO, Lane 1

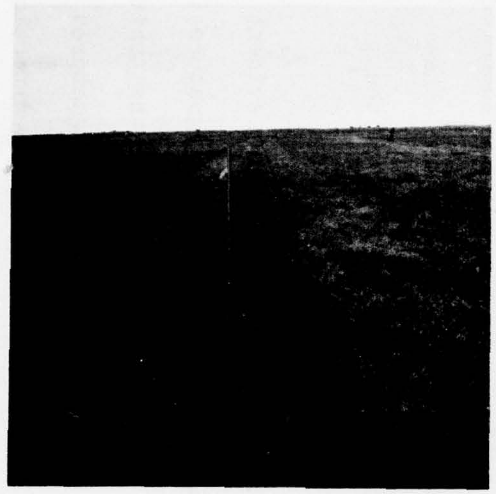


Fig. 9. 5 passes, CATCO, Lane 7

Fig. 10. 10 passes, CATCO, Lane 13

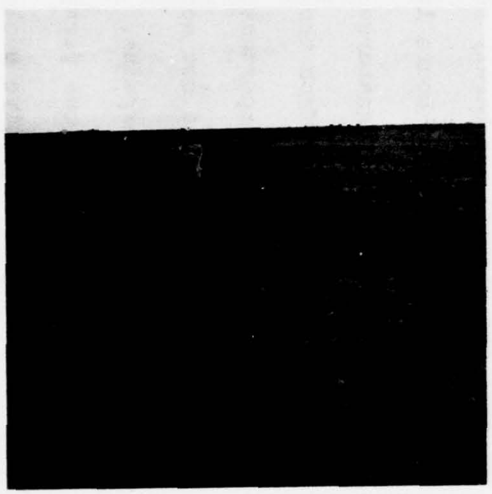


Fig. 11. 1 pass, CATCO, Lane 6

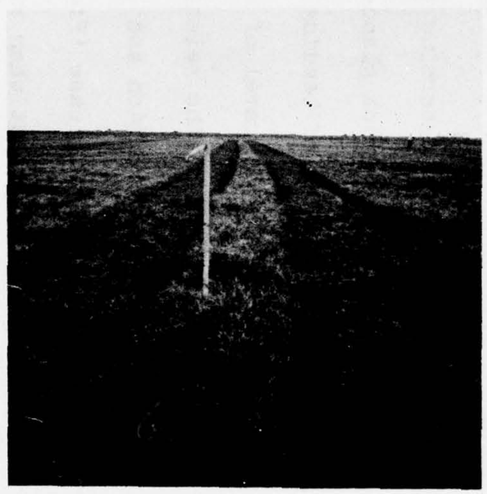


Fig. 12. 5 passes, CATCO, Lane 12

Fig. 13. 10 passes, CATCO, Lane 18

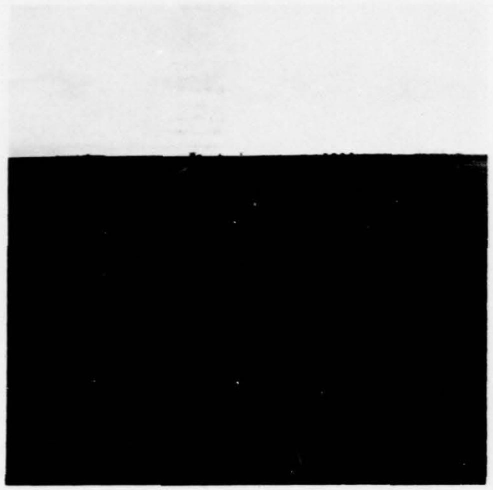


Fig. 14. 1 pass, Houston, Lane 2

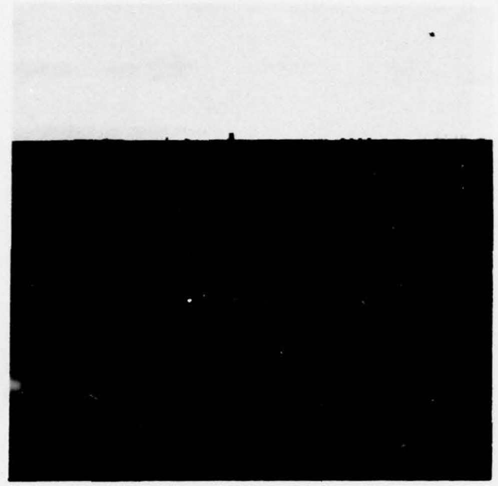


Fig. 15. 5 passes, Houston, Lane 8

Fig. 16. 10 passes, Houston, Lane 14

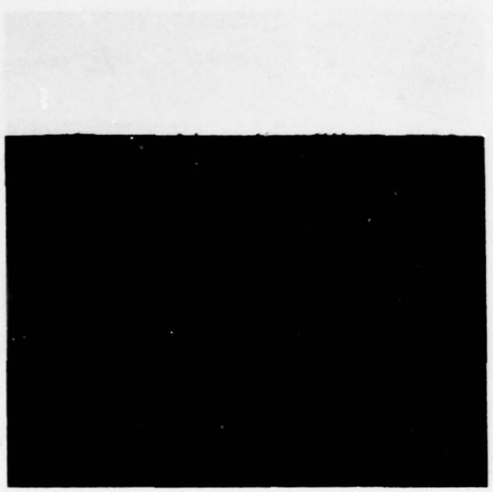


Fig. 17. 1 pass, Houston, Lane 5

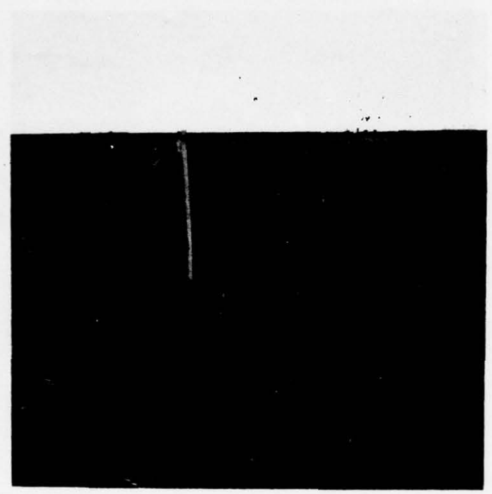


Fig. 18. 5 passes, Houston, Lane 11

Fig. 19. 10 passes, Houston, Lane 17

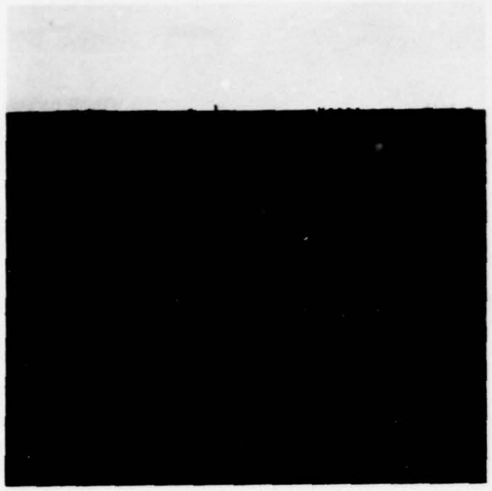


Fig. 20. 1 pass, Nodwell, Lane 3

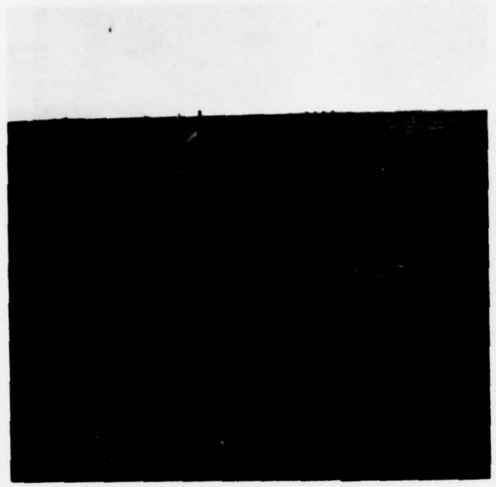


Fig. 21. 5 passes, Nodwell, Lane 9

Fig. 22. 10 passes, Nodwell, Lane 15

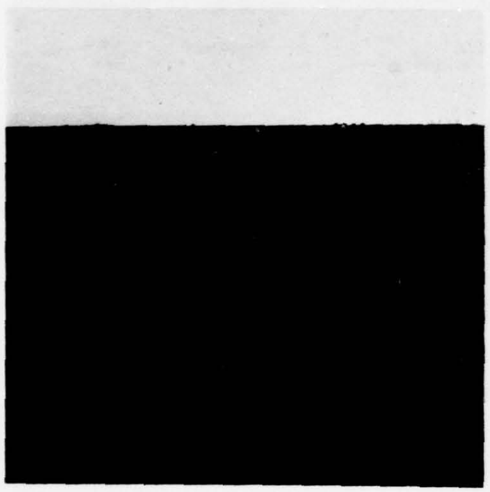


Fig. 23. 1 pass, Nodwell, Lane 4

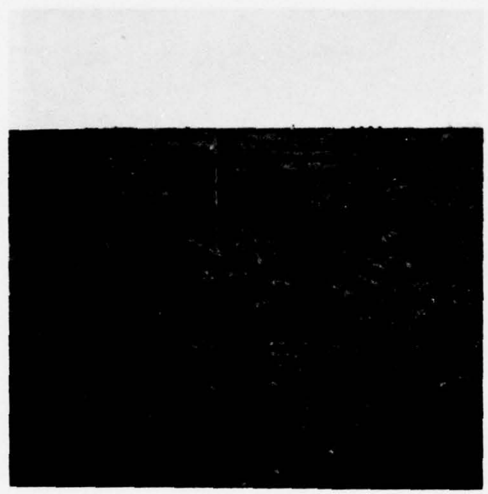


Fig. 24. 5 passes, Nodwell, Lane 10

Fig. 25. 10 passes, Nodwell, Lane 16

Terrain Surface Depression

The locations of the surface depression and thaw depth measurements across each lane are illustrated in Figure 26.

The depression left by a soft, wide rubber tire in a soft terrain is not uniform in cross-section; penetration below the center of tire can be considerably less than that below the edges, as shown in Figure 26. The surface depression measurements were, therefore, taken in the center as well as in both edges of the tire track. The center and edge depression data were treated separately (Tables 1 and 2), since the average would not be a very meaningful value.

In the wheeled vehicle (CATCO and Houston) test lanes, surface depression measurements were taken as follows: One measurement at each edge of each wheel track and one measurement in the center of each wheel track at both ends of the lane, a total of 8 measurements at the edge (y_e) and 4 measurements at the center (y_c) for each test lane.

In the tracked vehicle (Nodwell) test lanes, two surface depression measurements ($y_c = y_e$) were taken in each track at both ends of the lane, for a total of 8 measurements for each test lane (refer to Fig. 26).

Figure 27 shows in a cross-sectional format all the data obtained in this test area. The surface depression data, center and edge for both tracks of each lane, are shown graphically at an exaggerated vertical scale, with the corresponding thaw depth profiles plotted below.

Table 1 contains the surface depression and thaw depth data for both ends of the test lanes separately. (Note that the "thaw depth in track," h_T, measurements were obtained after the traffic tests, as shown in Fig. 26; therefore, the y_c value has to be added to the h_T to obtain the original thaw depth at that location.)

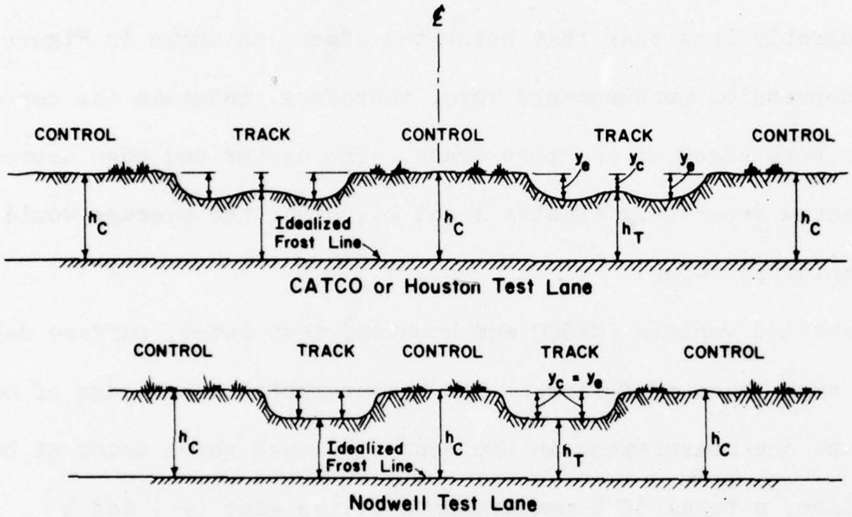


FIGURE 26. Location of thaw depth and surface depression measurements

TABLE 1. Thaw depth and surface depression data

Lane No.	Vehicle	No. of Passes n	Track (Left or Right)	South End of Lane: Thaw Depth (Control) h_C (cm)	South: Thaw Depth (Track) h_T (cm)	South: Surface Depression (Center) y_c (cm)	South: Surface Depression (Edge) y_e (cm)	North End of Lane: Thaw Depth (Control) h_C (cm)	North: Thaw Depth (Track) h_T (cm)	North: Surface Depression (Center) y_c (cm)	North: Surface Depression (Edge) y_e (cm)
1	C	1	L	25	22	0	0.5	21	22	0	0
			R		22	0	0		18	0	2
				23				22			
2	H	1	L	22	30	0	0	24	22	0	0
			R		22	0	0		24	0	0
				28				24			
3	N	1	L	20	20	0		22	24	0	
			R		22	0			24	0	
				23				19			
4	N	1	R	17	21	0		15	16	0	
			L		18	0			18	0	
				23				23			
5	H	1	R	24	22	0	0	17	17	0	0
			L		14	0	0		16	0	0
				26				19			
6	C	1	R	30	22	1	0.5	29	25	0	1.5
			L		29	0	0.5		24	0	0.5
7	C	5	L	28	27	0	3.5	25	27	1	1.5
			R		24	2	2.5		17	0	2
				28				20			
8	H	5	L	23	23	1	1.5	24	18	0	1
			R		19	0	1		23	0	1
				21				24			
9	N	5	L	25	22	1.5		21	21	1	
			R		19	0.5			21	2	
				22				26			
10	N	5	R	28	24	2		26	22	1	
			L		24	1			28	2	
				24				22			
11	H	5	R	-	23	1	1.5	25	22	1	2
			L		36	0	1.5		17	1	1.5
				27				22			
12	C	5	R	23	27	0	1.5	22	19	0	2
			L		23	1	2.5		24	2	4
13	C	10	L	24	17	1	2.5	25	22	2	6
			R		20	0	2.5		31	4	6.5
				26				32			
14	H	10	L	27	27	2	3	25	27	1	1.5
			R		26	3	3.5		21	2	2.5
				31				24			
15	N	10	L	27	25	2.5		31	25	2	
			R		26	1.5			28	2.5	
				25				31			
16	N	10	R	23	27	2.5		22	22	2.5	
			L		25	1.5			20	2	
				22				23			
17	H	10	R	25	15	1	2.5	23	20	3	4
			L		21	2	2.5		23	4	5
				36				21			
18	C	10	R	32	35	2	4	19	21	3	4.5
			L		28	2	4		23	0	4.5

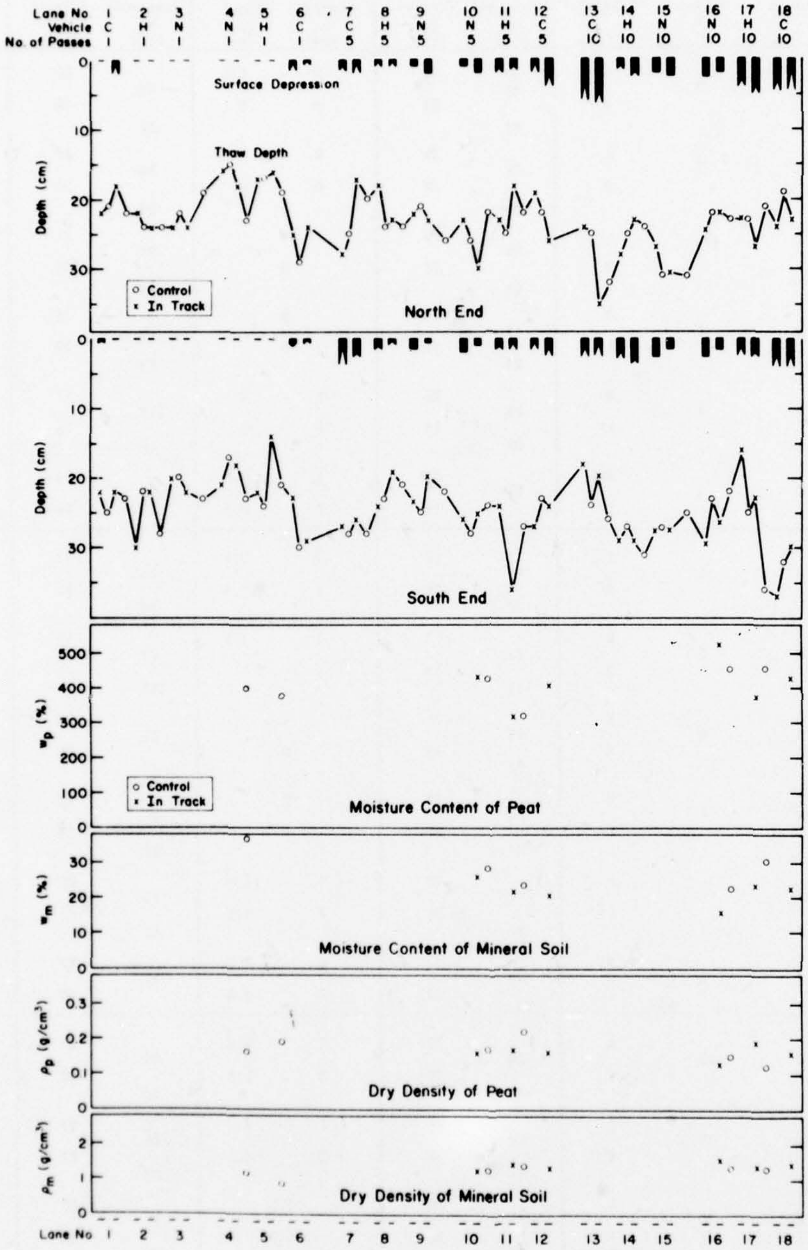


FIGURE 27. Surface depression, thaw depth, moisture content and dry density data plotted according to location

To determine whether or not there is any significant difference in the thaw depth between the north and the south ends of the lanes, mean values were calculated for each end of the three (1, 5, and 10-pass) traffic test areas:

Lane No.	Mean Thaw Depth (cm) South End	Mean Thaw Depth (cm) North End
1 - 6	22.9	21.1
7 -12	25.0	22.9
13 -18	26.6	25.5
Overall mean:	24.8	23.2

Each value above represents a mean of 23 measurements (control plus track data from Table 1); each overall mean value represents 69 measurements.

The mean thaw depth of the north end of the test area is 1 to 2 cm less than that at the south end. This difference can be considered insignificant when compared with local variations in thaw depth (refer to Figure 27).

More noticeable is the trend of increasing thaw depth towards east, but that difference (a few cm in the mean values) is also small in relation to local variations (Fig. 27).

There is no significant systematic change in the terrain characteristics (vegetation, relief or thaw depth) in either the North-South or East-West direction across the test area which would cause a systematic effect on the traffic test results. Variations in the results, such as the surface depression, are caused by the more prominent local variations in water content, density, relief, etc.

Table 2 summarizes the surface depression data for each test lane. The mean depression values for each test condition are plotted as cross-sections in Figure 28 (vertical scale exaggerated approximately 10 times that of horizontal). The immediate impression is that the smooth-tire CATCO caused the most sinkage and the tracked Nodwell the least. This is also evident from Figure 29, where the surface depression (at edge of track) is plotted vs the number of traffic passes. It should be noted that the CATCO had the highest ground pressure, the Nodwell had the lowest, and one vehicle pass with the CATCO represents 4 wheel passes, compared with only 3 for the Houston.

If the surface depression is plotted vs the number of wheel (instead of vehicle) passes, the difference between the CATCO and the Houston is no longer significant (Figure 31). There is, of course, no practical way to present the Nodwell traffic in terms of equivalent wheel passes.

The surface depression at the center of the track vs the number of vehicle and wheel passes is shown in Figures 30 and 32, respectively.

The terrain surface depression appears to increase proportionally with increasing traffic, at least up to 10 vehicle (30 to 40 wheel) passes. Thereafter, the sinkage-traffic curve may start to level off slightly if no shearing or disaggregation of the organic mat occurs, or it may begin to curve upward rapidly, if the durability of the organic mat is exceeded, resulting in complete mat failure and sinkage down to the frost line (refer to the previous Barrow tests in the Appendix).

Noticeably more damage to the terrain surface occurs when a vehicle is turning, because of the lateral shear forces caused by a tire and particularly by the hard edge of a track. The degree of damage increases with the vehicle's speed, with the amount of sinkage, and with a decrease in the turning radius.

TABLE 2. Surface depression, mean values

Lane No.	Vehicle	No. of Passes n	Mean Surface Depression (Center) y_c (cm)	(Edge) y_e (cm)
1	CATCO	1	0	0.6
6			0.2	0.8
2	Houston	1	0	0
5			0	0
3	Nodwell	1	0	
4			0	
7	CATCO	5	0.8	2.4
12			0.8	2.5
8	Houston	5	0.3	1.1
11			0.7	1.6
9	Nodwell	5	1.3	
10			1.5	
13	CATCO	10	1.8	4.4
18			1.8	4.2
14	Houston		2.0	2.6
17			2.5	3.5
15	Nodwell	10	2.1	
16			2.1	

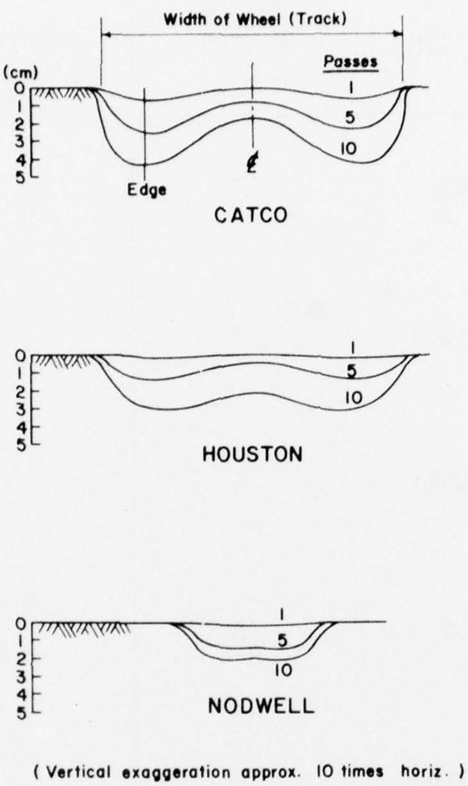


FIGURE 28. Surface depression caused by traffic

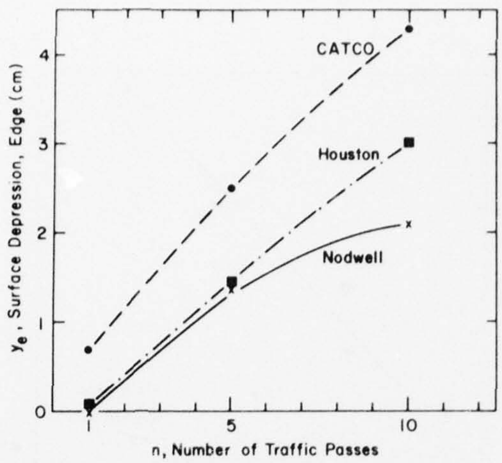


FIGURE 29. Surface depression at edge of track vs number of traffic passes

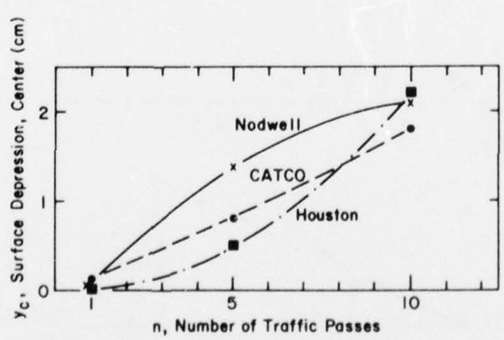


FIGURE 30. Surface depression in center of track vs number of traffic passes

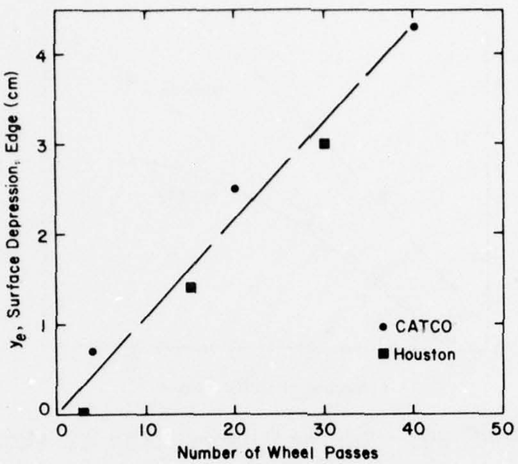


FIGURE 31. Surface depression at edge of track vs number of wheel passes

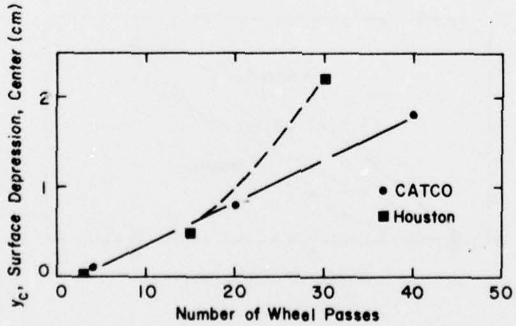


FIGURE 32. Surface depression in center of track vs number of wheel passes

Vegetation and Soil Properties

The moisture content and dry density data are listed in Table 3 (refer to Fig. 7 for the locations of these measurements; the data are also plotted in Fig. 27). The peat thickness and thaw depth data at these measurement sites are also shown.

Since only a limited amount of data were obtained, it is not really possible to determine the impact of traffic on the moisture content and density conclusively. However, to investigate whether there was any apparent effect from the traffic, the data from below the vehicle tracks were plotted vs the closest adjacent control data (refer to Table 3 and Fig. 27). No data were obtained in the 1-pass tracks.

Figure 33 shows the moisture content of peat below the track, $w_{p(T)}$, vs the adjacent control area, $w_{p(C)}$. The $w_{p(T)} = w_{p(C)}$ condition is represented by the straight line. No conclusions can be drawn from this graph. However, the effect on the moisture content in the mineral soil is more evident (Fig. 34). There appears to be some decrease in the moisture content of the mineral soil below the trafficked area. This observation, combined with the evidence that there may have been some increase in the dry density of the mineral soil (Fig. 36), implies that the mineral soil has been subjected to some degree of compaction due to traffic. Any comparable influence on the dry density of peat is not conclusive from the available data (Fig. 35).

TABLE 3. Moisture content and dry density data

Lane No.	Vehicle	Location*	No. of Passes n	Peat Thickness (cm)	Thaw Depth h (cm)	Moisture Content (Peat) w_p (%)	Moisture Content (Mineral) w_m (%)	Dry Density (Peat) ρ_p (g/cm^3)	Dry Density (Mineral) ρ_m (g/cm^3)
		Control		12	25	394	36.8	0.16	1.14
5	Houston	R	1						
		L							
		Control		14	21	375	55.0	0.19	0.86
		Control							
10	Nodwell	R	5						
		L		13	28	429	25.8	0.16	1.27
		Control		12	27	425	28.5	0.17	1.26
11	Houston	R	5						
		L		9	25	314	21.7	0.17	1.50
		Control		12	24	318	23.4	0.22	1.40
12	CATCO	R	5						
		L		11	25	406	20.7	0.16	1.34
		Control							
		Control							
16	Nodwell	R	10						
		L		15	22	523	15.8	0.13	1.58
		Control		13	27	452	22.4	0.15	1.34
17	Houston	R	10						
		L		10	16	370	23.4	0.19	1.36
		Control		14	25	455	30.6	0.12	1.33
18	CATCO	R	10						
		L		14	35	428	22.4	0.16	1.45
		Control							

* R or L denotes right or left track of test lane; note that measurements were taken in the left track.

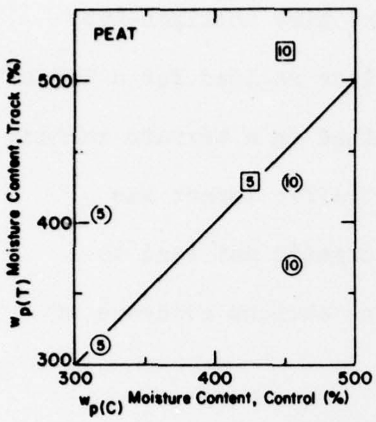


FIGURE 33. Moisture content of peat, track vs control

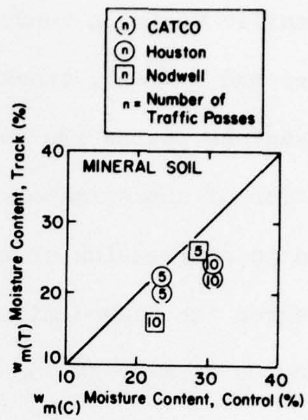


FIGURE 34. Moisture content of mineral soil, track vs control

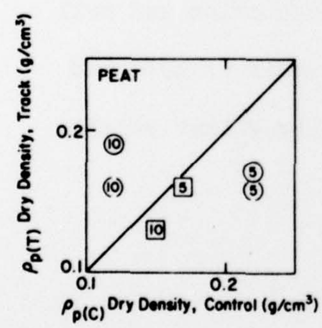


FIGURE 35. Dry density of peat, track vs control

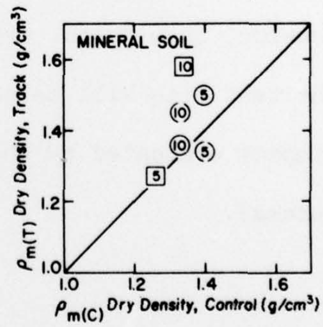


FIGURE 36. Dry density of mineral soil, track vs control

SUMMARY AND CONCLUSIONS

Traffic tests on tundra with two, low pressure tire Rolligon-type vehicles and a small, tracked Nodwell with minimal or no load for a total of 10 vehicle passes (30 to 40 wheel passes) resulted in a terrain surface depression of approximately 4 cm (maximum). The traffic impact was limited to compression of the vegetation and the organic mat (and to some degree the thawed mineral soil below), with no obvious evidence of shearing or disaggregation of the mat.

It is expected that all of the traffic lanes will recover, the surface depression and the disturbance of the active layer being a short term impact (a few years), the visibility of the vehicle tracks ("green belt" effect) lasting somewhat longer. It has been observed (Abele, 1976) that a depressed, but unsheared, organic mat displays considerable ability to rebound during a period of a few summers.

It is planned to make annual visits to the test area to monitor the test lane conditions with photographs and measurements (surface depression, thaw depth, water content, density). Vegetation and soil of the test site will be characterized during the summer of 1977 and the impact evaluated by the rating scheme described by Walker et al. (in press).

BIBLIOGRAPHY

Abele, G. (1976) Effects of Hovercraft, Wheeled and Tracked Vehicle Traffic on Tundra, Proceedings of the 16th Muskeg Research Conference, NRC Canada.

Abele, G. and Brown, J. (1977) Arctic Transportation: Operational and Environmental Evaluation of an Air Cushion Vehicle in Northern Alaska, "Journal of Pressure Vessel Technology," Feb. 77, Vol. 99, ASME Paper No. 76-Pet-41.

Burt, G. R. (1970a) Summer Travel on the Tundra with Low Ground Pressure Vehicles, Institute of Arctic Environmental Engineering, Univ. of Alaska, N7004.

Burt, G. R. (1970b) Travel on Thawed Tundra, Institute of Arctic Environmental Engineering, Univ. of Alaska, N7005.

Kevan, P. G. (1970) Vehicle Tracks on High Arctic Tundra, Defence Research Board, Ottawa, Canada, "Hazen 41."

Miller, P.C., Stoner, W.A., and Barkley, S.A. (1977) Computer Simulations of Potential Off-Road Vehicle Effects on Tundra, San Diego State Univ., San Diego, CA (USACRREL Internal Report).

Radforth, J.R. (1970) Rolligon Tundra Disturbance Tests, Tuktoyaktuk, Muskeg Research Institute, Univ. of New Brunswick, Report prepared for Bechtel, Inc.

Radforth, J.R. (1972) Analysis of Disturbance Effects of Operations of Off-Road Vehicles on Tundra, Muskeg Research Institute, Univ. of New Brunswick, ALUR 71-72-13.

Radforth, J.R. (1973a) Immediate Effects of Wheeled Vehicle Traffic on Tundra During the Summer, Muskeg Research Institute, Univ. of New Brunswick, ALUR 72-73-12.

Radforth, J.R. (1973b) Long Term Effects of Summer Traffic by Tracked Vehicles on Tundra, Muskeg Research Institute, Univ. of New Brunswick, ALUR 72-73-13.

Rickard, W.E. and Brown, J. (1974) Effects of Vehicles on Arctic Tundra, "Environmental Conservation," Vol. 1, No. 1.

Sterrett, K.F. (1976) The Arctic Environment and the Arctic Surface Effect Vehicle, USACRREL Report 76-1.

Walker, D.A., Webber, P.J., Everett, K.R., and Brown, J. (1976) The Effects of Low-Pressure Wheeled Vehicles on Various Plant Communities and Soils at Prudhoe Bay, Alaska, USACRREL Special Report (in press).

APPENDIX: ROLLIGON TESTS, BARROW, 1974

On 7 August 1974, three test lanes, 1, 5 and 15 traffic passes, were made with a 4-wheel Rolligon Vehicle (Fig. A-1) at a site approx. 4 miles southeast of Barrow, near the Ikpik Slough, where Air Cushion Vehicle (ACV or SEV) and Weasel traffic tests had been conducted during the summer of 1971. The test area is on a level, drained lake bottom, with a relatively uniform and homogeneous saturated active layer and vegetation, the organic mat having a moisture content of approx. 1000% and thaw depth in the 20 to 30 cm range.

The Rolligon tests were not planned; they were done on the spur-of-the-moment during inspection of the 3-year old ACV and Weasel test lanes. During subsequent monitoring of the ACV and Weasel lanes in 1975, 1976, and 1977, photographs of the Rolligon lanes were also taken.

The test vehicle had ribbed (cleated) tires with an inflation pressure between 0.2 and 0.3 kg/cm^2 (approx. 3 to 4 psi) and carried no load. In one section of the 15-pass lane, initially intended for 25 passes, the Rolligon tires had penetrated through the active layer almost down to the permafrost after 10 passes; traffic was therefore, stopped after 15 passes.

Figure A-2 shows the cross-sections of the Rolligon test lanes. For the 15-pass lane, two cross-sections are shown, one for the area where complete failure of the thawed layer occurred (south end of lane) and the other where the terrain was slightly elevated, drier and had a higher frost line (north end of lane) and thus only partial failure had occurred.

During traffic on the 15-pass lane, a visual observation was made on the apparent failure mechanism of the organic mat, i.e., how the mat is gradually weakened to the point of failure with repeated traffic. This is shown and explained in Figure A-3.

Figures A-4 through A-15 show the Rolligon test lanes immediately after traffic, and after 1, 2 and 3 years.

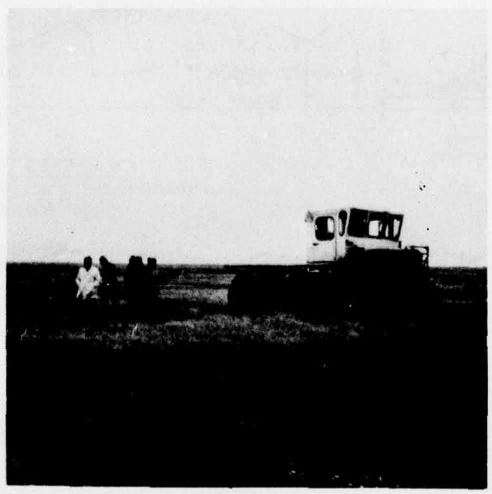


FIGURE A-1. Rolligon vehicle used for traffic tests. Ribbed (cleated) rubber tires; tire inflation pressure (and approximate ground contact pressure) between 0.2 and 0.3 kg/cm^2 (3 to 4 psi); no load, except for 2 men and fuel.

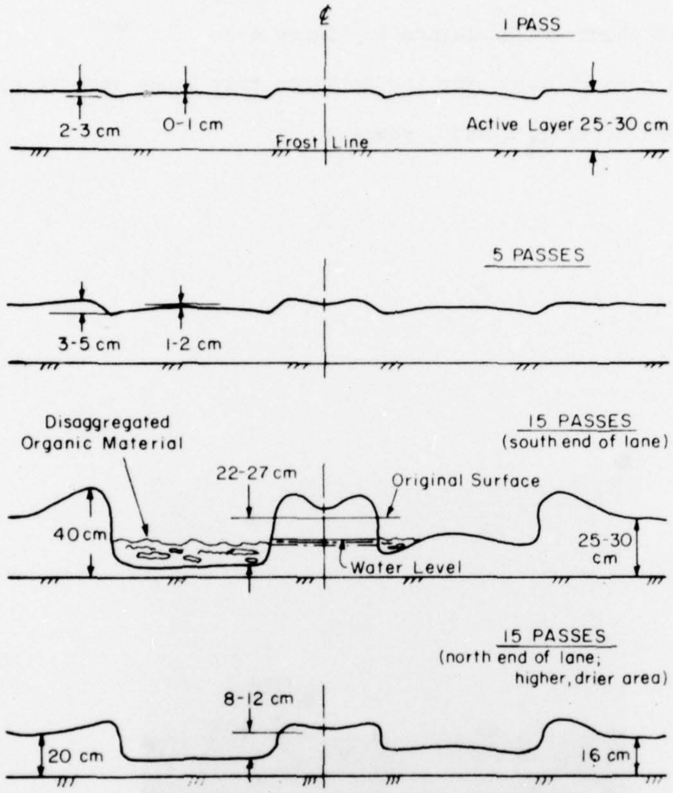
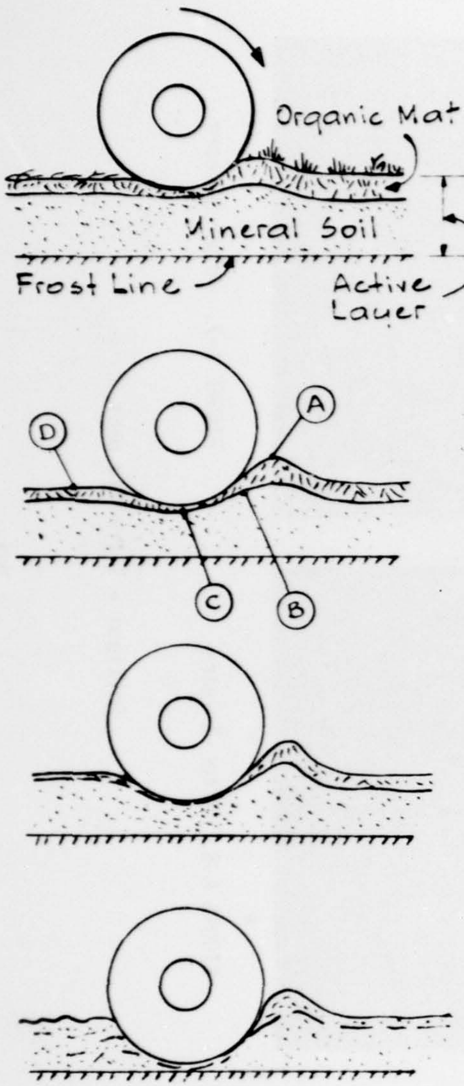


FIGURE A-2. Cross-sections of Rolligon test lanes



During travel over saturated tundra, a wave is formed in front of the tire; the organic mat is subjected to some flexing and longitudinal (in the direction of travel) stressing in front of the tire, lateral (perpendicular to the direction of travel) tension when tire sinkage occurs, and compaction below the tire.

During repeated traffic passes, the wave being pushed ahead of the tire becomes more prominent (increased amplitude); the organic mat is subjected to repeated horizontal and vertical stresses. Immediately in front of the tire and through the crest of the wave, the surface of the organic mat (A) is pushed up and ahead further than the bottom of the mat (B), causing longitudinal shear and thus tearing of the root system between (A) and (B). At (B) there is also some weakening of the bond between the organic mat and the mineral soil because of lifting of the mat. Below the tire (C), the mat is not only under vertical compression, but is also subjected to longitudinal and lateral tension because of depression (and thus stretching) due to the non-rigid mineral soil layer below. There is obviously some disturbance of the mineral soil in front of the tire below the wave (longitudinal shear) and below the tire (compression, resulting in water being squeezed out laterally), causing some weakening of the water-soil matrix. There is some rebound of the organic mat, and perhaps the mineral soil, at (D); but this is a very slow process.

This is the critical phase in the supporting capacity of the active layer. The continuous stretching of the organic mat, due to repeated traffic, has caused a systematic breakdown (tearing) of the organic fibers, particularly the root system (which is the principal source of strength of the mat). And, the cyclic tension and compression have degraded whatever structural integrity the saturated mineral soil may have had. If, at this point (that is, before the tire shears through the organic mat) the trail is not subjected to any more traffic, recovery is quite likely.

Once the fatigue point of the organic mat has been reached, additional traffic passes will cause complete failure of the mat and penetration of the tire through the mineral soil layer, since the latter has little strength of its own. When this happens, recovery of the traffic trail will, most likely, not occur; in fact, degradation may continue and increase with time. It should be noted that, depending on the soil properties and vehicle (or tire) characteristics, the failure point of the active layer can be reached or exceeded during the first pass of a vehicle.

FIGURE A-3. Failure mechanism of tundra under traffic

FIGURE A-4. After test

FIGURE A-5. After 1 year

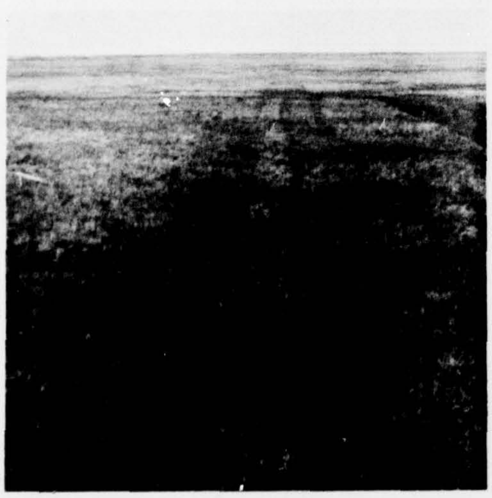


FIGURE A-6. After 2 years

FIGURE A-7. After 3 years

Rolligon - 1 traffic pass

FIGURE A-8. After test

FIGURE A-9. After 1 year

FIGURE A-10. After 2 years

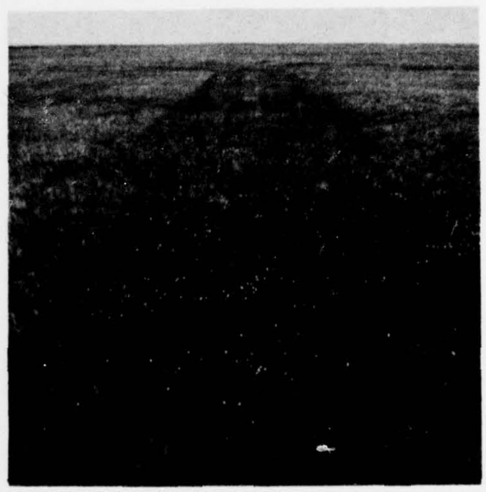


FIGURE A-11. After 3 years

Rolligon - 5 traffic passes

FIGURE A-12. After test

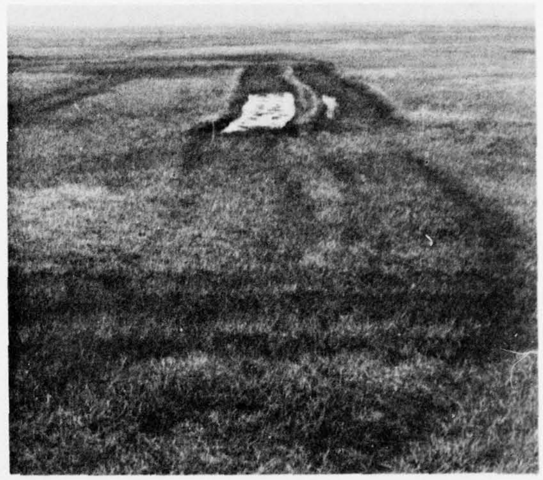


FIGURE A-13. After 1 year

FIGURE A-14. After 2 years

FIGURE A-15. After 3 years

Rolligon - 15 traffic passes